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EFFECTS OF TILLAGE AND NITROGEN FERTILIZATION ON SOIL ORGANIC CARBON AND MAIZE PERFOMANCE IN THE SOUTHERN GUINEA SAVANNA OF NIGERIA

[*1]Are, E. C., [2]Adeboye, M. K. A., [2]Odofin, A. J. and [2]Eze, P. C.
[1]Department of Soil and Environmental Management, Prince Abubakar Audu University, P.M.B. 1008, Anyigba. Kogi State, Nigeria.
[2]Department of Soil Science and Land Management, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.
***Corresponding Author's E-mail**: areezekiel16@gmail.com **GSM**: +2347037113680

ABSTRACT
The study evaluates the effects of tillage and split nitrogen fertilization on soil organic carbon and maize performance in the rainy season of 2022 at Anyigba, southern Guinea savanna agro ecological zone of Nigeria. The treatments were tillage practices with two levels, manual ridging (MR) and minimum tillage (MT) and split nitrogen fertilization with five levels 0, 30 + 60, 45 + 45, 60 + 30 kg N ha^{-1} applied in split form at 2 weeks after planting and at tasseling growth stage and 90 kg N ha^{-1} full dose applied at 2 weeks after planting. The experimental design was 2 x 5 factorial fitted to randomized complete block design with three replicates. The results showed that there was no significant effect of the treatments on seedling emergence. Manual ridging recorded significantly higher soil organic carbon content with mean value of 28.72 g kg^{-1} at 2 weeks after planting compared with minimum tillage. Tillage significantly affected maize grain yield with MR recording 1.3 Mg ha^{-1} which was significantly higher than 1.2 Mg ha^{-1} recorded for MT. There was response to N fertilization with the N fertilized treatments having significantly higher grain yield than the control treatment. The split application of N, 60 + 30 kg N ha^{-1} produced the highest grain yield of 2.2 Mg ha^{-1} which was significantly higher than of the split, 30 + 60 kg N ha^{-1} and the zero N treatment. Manual ridging and split application of recommended rate of N seem to be the most appropriate for maize production in the area.
Key words: Carbon, Guinea, Maize, Nitrogen, and Organic

INTRODUCTION
Conservation agriculture (CA) is a system of farming that involves minimum soil disturbance, (zero and minimum tillage), crop residue retention and crop rotations, this is considered as a soil and crop management system that could potentially increase soil quality and crop yield (FAO, 2008). It offers an opportunity to reverse land degradation that prevails in many parts of sub-Saharan Africa due to its positive effects on enhancement of physical, biological and chemical properties of soil when compared to conventional tillage practices (Madari *et al.,* 2008; Wander and Yang, 2000). Conservation agriculture is an approach that aims to sustainably improve farm productivity, profits and food security characterized by three principles: minimum soil disturbance, crop residue retention and diversified crop rotations. The three principles increase soil organic carbon, minimize erosion risk, conserve soil water, decrease fluctuations in soil temperature, enhance soil quality and soil's environmental regulatory capacity. Ultimately, CA optimizes crop yields and reduces input costs. (Hobbs, 2007).

Soil tillage is the mechanical manipulation of the soil for the purpose of crop production. It negatively affects water conservation, soil temperature, infiltration and evapotranspiration processes. Derspsch *et al.* (2006) reported that continuous cultivation under tillage agriculture leaves soil bare and unprotected, thereby promoting accelerated soil erosion, soil nutrient depletion

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and soil structural deterioration consequent upon the decline in soil organic matter. This decline is due mainly to accelerated microbial decomposition of organic residues due to improved soil aeration from tillage operations and destruction of aggregates that exposes the high surface area coupled with the release of aggregated-protected organic matter for mineralization. (Govaerts *et al.*, 2009). Conservation agriculture has been reported to mitigate these problems arising from continuous soil tillage (Grahmann *et al.,* 2013).

Soil organic matter is a heterogeneous mixture of products synthesized by the microbial, chemical and biochemical transformation of plant and animal residues disposed through the soil. It serves as a source of, and a temporary sink for several plant nutrients including micronutrients and potentially toxic metals in the soil environment (Agbenin, 2020). Soil organic matter has a strong influence on soil biological, chemical, and physical properties and crucial soil functions and serves as an important indicator of soil quality with direct implications for crop productivity, food security, and human livelihood (Zingore and Njoroge, 2022).

Maize production has increased over the years in both humid rainforest and moist savannas of Nigeria. It is an enormously important crop grown for human consumption and used as animal feed and agro-industrial raw material. However, maize is a heavy feeder that is easily affected by soil degradation (Badu-Apraku and Fakorede, 2017; IITA, 2017). The total annual production has increased from 1.06 M tons in 1976, to 11.6 M tons in 2016 (FAO, 2018). Maize productivity is largely depending on nutrient availability particularly nitrogen, phosphorus and potassium and management practices (Rasheed *et al.,* 2004). Therefore, this has necessitated the need to evaluate the effects of tillage and nitrogen fertilization on selected soil organic carbon and maize performance in southern guinea savanna of Nigeria.

One of the major constraints to adoption of CA is poor availability and quality of crop residues that are essential for mulching to achieve one of the three basic principles of CA, prevention of soil erosion. The poor quality of the mulching materials in the form of grass or cereal stover available with high C: N ratio results in short-term immobilization of N. This negative effect can be offset by application of large amounts of N fertilizer in the early years of CA. This is because net mineralization from grass or cereal stover residues may only be achieved in the long-term (Kafesu *et al*., 2018). In Nigeria, there is dearth of knowledge which has been documented on the effect of N management in the early years of CA on the soil organic carbon and performance of maize. Therefore, the objective of this study was to evaluate the effect of N fertilization on soil organic carbon and maize performance in the early years of CA at Anyigba, Kogi State in the southern Guinea savanna of Nigeria.

MATERIALS AND METHODS

The Study Area

The study site was the Teaching and Research Farm of Prince Abubakar Audu University, Anyigba, Kogi State, in the Southern Guinea savanna agro-ecological zone of Nigeria on latitude 7º 10′ 30″ N and longitude 7º 28′ 50″ E, at an altitude of 289 m above sea level. The climate of Anyigba is sub-humid with average annual rainfall and temperature of 1260 mm and 27 °C respectively. The rainfall, minimum and maximum temperature data of the site during the period of study were presented in Table 1. The area lies in the derived savanna vegetation zone of Nigeria. Derived savanna is evolved from the rain forest by human activities such as regular fire, deforestation and farming (Adekiya *et al.,* 2018). The physical features of the site are flat to gently undulating lowlands filled with Cretaceous and Tertiary rocks over which the rivers have been cut. The soils are Eutric Gleysols and Eutric Fluvisols mainly developed from a wide range of alluvial

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materials (Ojanuga, 2006). Prior to the research, the field has been cultivated to sorghum and maize with little fertilizer application over a long period of time.

Treatments and Experimental Design

The treatments were two tillage practices with two levels, minimum tillage and manual tillage, and nitrogen management practices with five levels, 0 kg N ha^{-1}, 90 kg N ha^{-1} applied in split form of 30 kg N ha^{-1} at 2 weeks after planting (WAP) and 60 kg N ha^{-1} applied at tasseling growth stage (recommended practice), 45 kg N ha^{-1} applied at 2 WAP and 45 kg N ha^{-1} applied at tasseling growth stage, 60 kg N ha^{-1} applied at 2 WAP and 30 kg N ha^{-1} applied at tasseling growth stage and 90 kg N ha^{-1} applied at once at 2 WAP. The experimental design was 2 x 5 factorial fitted to a randomized complete block design (RBCD) with three replicates to give a total of 30 experimental plots and 10 treatment combinations (Table 2). The gross plot size was 5 m x 5 m (25 m^2), while the net plot size was 3 m x 3 m (9 m^2).

Table 1: Monthly Climatic Data Observed in Anyigba during the Grow Period (Jun – Sept, 2022)

Month	Rain (mm)	Temperature (°C)	
		Minimum	Maximum
June	400.0	24.7	34.1
July	400.2	25.0	35.1
August	598.5	24.8	33.2
September	500.6	23.9	35.0

Source: National Agency for Space and Research Development Authority Anyigba Station

Table 2: Treatment designation, combinations and description.

Treatment designation	Treatment Combination	Description
A	MTN_0	Minimum tillage with no N fertilizer
B	MRN0	Manual ridging with no N fertilizer
C	MT90N (30 + 60)	Minimum tillage with 30 kg N ha^{-1} applied at 2 WAP and 60 kgNha^{-1} applied at tasseling growth stage
D	MR90N (30 + 60)	Manual ridging with 30 kg N ha^{-1} applied at 2 WAP and 60 kg N ha^{-1} applied at tasseling growth stage
E	MT90N (45 + 45)	Minimum tillage with 45 kg N ha^{-1} applied at 2 WAP and 45 kg N ha^{-1} applied at tasseling growth stage
F	MR90N (45 + 45)	Manual ridging with 45 kg N ha^{-1} applied at 2 WAP and 45 kg N ha^{-1} applied at tasseling growth stage
G	MT90N (60 + 30)	Minimum tillage with 60 kg N ha^{-1} applied at 2 WAP and 30 kg N ha^{-1} applied at tasseling growth stage
H	MR90N (60 + 30)	Manual ridging with 60 kg N ha^{-1} applied at 2 WAP and 30 kg N ha^{-1} applied at tasseling growth stage
J	MT90N	Minimum tillage with 90 kg N ha^{-1} applied at 2 WAP
K	MR90N	Manual ridging with 90 kg N ha^{-1} applied at 2 WAP

Agronomic Practices

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The field was cleared and ridged at 75 cm apart manually with the litters and weeds incorporated into the soil making the surface bare. The minimum tillage plots had the land prepared by the use of hoe to make small heaps also at 75 cm apart along the planting lines. Growing weeds were controlled by spraying with the Atrazine at the rate of 0.25 kg ha^{-1} as pre-emergence three days after planting using knapsack sprayer. The resulting debris and other surface soil litter were left on the soil as mulch; maize variety, Sammaz 52 (PVA SYN 13) yellow maize, medium maturity between 110 and 120 days, tolerant to maize streak virus, rust, leaf blight and auricularia leaf spot. Three seeds were planted per hole at 25 cm intra-row spacing and thinned to one seed at 2 WAP to give a total plant population of about 53,330 plants ha^{-1}. All the plots had basal fertilizer application of 60 kg P_2O_5 ha^{-1} using single superphosphate and 60 kg K_2O ha^{-1} using muriate of potash fertilizer. Urea fertilizer was used to supply N for plots requiring N fertilizer and for plots requiring split application, the first dose was applied at 2 WAP while the second dose was applied at tasseling growth stage of maize. All fertilizer applications were by split placement about 5 cm away and 5 cm deep at the base of each plant stand and covered with soil. Weeding was done manually with hoe where necessary at 2 WAP and 4 – 5 WAP before fertilizer application where necessary. All residues from weeding were left on the surface of the soil.

Soil sampling and analysis

In order to characterize the whole field prior to the commencement of the study in 2022 surface soil (0-20 cm) samples were collected using auger from three diagonal transects at 5 m regular intervals and each bulked together to give 3 composite samples for the routine analysis. Samples were also collected along three diagonals transect from each plot and bulked together to give one sample for the determination of soil organic carbon at various growth stages.

The samples were air-dried, gently crushed using a porcelain mortar and pestle and then sieved with a 2 mm mesh. The routine physical and chemical analysis to characterize the field was determined according to the procedure described by Okalebo *et al.,* (2002). Briefly, particle size analysis was determined by Bouyorcos hydrometer method. Soil reaction determined potentiometrically in 1:2.5 Soil to water suspension using the glass electrode pH meter. Organic carbon determined by the Walkley and Black wet oxidation method, total nitrogen was determined by Kjeldahl digestion method. Available phosphorus was extracted by Bray P-1 and the P concentration in the extract was determined colormetrically using spectrophotometer. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) was extracted using 1 NH_4OAC buffered at pH 7.0. Ca^{2+} and Mg^{2+} was determined using atomic absorption spectrophotometer while K^+ and Na^+ determined using flame photometer. Exchangeable acidity was determined by titration method using 1N KCl extract. Effective cation exchange capacity (ECEC) was estimated by calculation by summing the exchangeable bases and exchangeable acidity.

Growth Analysis

Plant height

The height of maize plants was taken from 10 tagged plants within the net plot and averaged at 2 WAP, tasseling growth stage and physiological maturity of the plant. The height was measured from the ground level to the apical tip of the tallest leaf using a meter rule.

Yield and yield component analysis

At harvest, maize ears and stalk in the net plot were collected and further air-dried, after which the ears were shelled and resulting grain, cobs and stover weighed to determine grain and total dry matter yield. The grain yield was determined at 12 % moisture content.

Analytical Technique

Data collected were subjected to analysis of variance (ANOVA) and mean separation where significant was carried out using Duncan's New Multiple Range Test (DNMRT) at 5 % level of probability, unless otherwise state.

Table 3: Initial properties of the soil prior to land preparation

Soil properties	Values
Sand (g kg^{-1})	831
Silt (g kg^{-1})	66
Clay	103
Textural Class	**Loamy Sand**
pH (H_2O) 1:2.5	6.1
Organic Carbon (g kg^{-1})	6.8
Total Nitrogen (g kg^{-1})	0.70
Available Phosphorus (mg kg^{-1})	6.0
Exchangeable Cations (cmol kg^{-1})	
Ca	4.02
Mg	2.26
K	2.02
Na	0.33
Exchangeable Acidity (cmol kg^{-1})	1.02
ECEC (cmol kg^{-1})	9.65

RESULTS AND DISCUSSIONS

Initial soil properties

The initial properties of the soil at the commencement of the experiment are shown in Table 3. Sand was the dominant fine earth fraction in the soil with a value of 831 g kg^{-1}. The textural class of the soil was loamy sand. The coarse nature of the soil indicates low water holding capacity and availability. The sandy nature of the soil allows for tillage of the soil, even at high moisture content with less drainage to the structure of the soil. The pH of the soil was 6.1. This falls within slightly acidic range of pH which is optimum for most crops. The pH range of 6.0 – 7.0 is the most suitable for the release of many plant nutrients for uptake and optimum growth and development of most plants (Tan, 2000). The soil organic carbon content was 6.8 g kg^{-1} and the total N content was 0.70 g kg^{-1}, which were respectively within moderate and low range classes.

Available phosphorus of the soil falls within low class and was 6.0 mg kg^{-1}. The moderate organic carbon with consequent low N and Pare characteristics of savanna soils, due partly to rapid decomposition in tropical climates which makes it difficult to build-up soil fertility. The result from the determination of exchangeable cations showed that Ca concentration was 4.02 cmol kg^{-1} (low), Mg was 2.26 cmol kg^{-1}(moderate), K was 2.02 cmol kg-^{1}(very high) and Na was 0.33 cmol kg^{-1}(moderate). The low content of Ca and Mg is a reflection of the low clay and moderate organic matter contents of the soil. In tropical soils, organic matter is the main source of negative charges that these nutrients are adsorbed to, which prevents them from being leached down the soil profile beyond the root zone (Brady and Weil, 2010). The exchangeable acidity ($Al^{3+}+H^{+}$) was low, 1.02 $cmol^{-1}$. The soil is thus low in potential acidity and will not contribute to the active acidity, may not constitute toxicity to crops which can have an adverse effect on root development (Adeboye *et al*, 2020) High amount of aluminum is toxic to roots and cause swelling of the roots impending their ability to absorb water and nutrients from the soil (Brady and Weil, 2010). Effective Cation Exchangeable Capacity (ECEC) was moderate, 9.65 cmol kg^{-1}, which is a reflection of the moderate organic carbon content.

Soil organic carbon as affected by tillage and split nitrogen fertilization

The soil organic carbon (SOC) at the growth stages of maize is shown in Table 4. The SOC was significantly affected by tillage and split nitrogen fertilization only at 2 WAP. Manual ridging recorded 28.72 g kg^{-1} which was significantly higher than 24.79 g kg^{-1} for MT at 2 WAP. For split nitrogen fertilization, 45 + 45 kg N ha^{-1} recorded the highest value of 29.80 g kg^{-1} at 2 WAP which was not significantly different from the 60 + 30 kg N ha^{-1} treatment.

Tillage enhances mineralization of soil organic matter. The higher SOC in MR at 2 WAP compared with MT could be due to enhanced mineralization of organic matter and consequent release of nutrients. Lower SOC content at tasseling and maturity could be as a result of the rapid mineralization of soil organic matter experienced in the tropical agro ecological zones due to favourable condition for microbial activities (Agbenin, 2020). Increase in SOC due to application of nitrogen could be attributed to enhanced rapid decomposition of soil organic matter. Nitrogen fertilization has been reported to increase SOC at tasseling and maturity of maize by Agbede *et al.* (2008). The introduction of tillage increases the organic carbon storage in the cultivated layer 0-15 cm 0.19 to 0.81 Mg ha^{-1} year (Baker *et al.,* 2007). The interaction between tillage and N fertilization revealed that SOC was significant only at 2 WAP. This is to be expected as significant effect of tillage and N fertilization was observed only at seedling stage of maize. Manual ridging combined with split application of N, 45 + 45 and 60 + 30 kg N ha^{-1} recorded the highest content of SOC which were significantly different from other treatments.

Table 4: Effect of tillage and split nitrogen fertilization on soil organic carbon (g kg^{-1})

Treatment	Organic carbon		
Tillage (T)	2WAP	Tasseling	Physiological maturity
MR	28.72^{a}	11.43^{a}	15.74^{a}
MT	24.79^{b}	10.32^{a}	14.63^{a}
SE ±	1.04	1.75	1.06
N rate (Kg N ha^{-1})			
0	25.32^{b}	7.80^{a}	13.62^{a}
30 + 60	25.95^{b}	12.13^{a}	15.82^{a}
45 + 45	29.80^{a}	12.45^{a}	16.15^{a}
60 + 30	27.82^{ab}	12.68^{a}	14.93^{a}
90	24.88^{b}	9.32^{a}	15.40^{a}
SE ±	1.64	2.77	1.69
Interaction			
T x N	X	NS	NS

All means within a column (for each factor) followed by same letters are not significantly different
At 5% level of significance. MR= Manual ridging, MT = Minimum tillage, SE = Standard error, OC =Organic carbon, WAP = Week after planting, TAS = Tasseling, PMAT = Physiological Maturity, NS = Not significant at 5% level

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Table 5: Effect of Interaction effect of tillage and split nitrogen fertilization on soil organic carbon at 2WAP (g kg^{-1})

Treatment / N-mgt (kg N ha^{-1})	0	30 + 60	45 + 45	60 + 30	90
MR	24.93^{b}	26.20^{b}	35.57^{a}	32.23^{a}	24.67^{b}
MT	25.70^{b}	25.70^{b}	24.03^{b}	23.40^{b}	25.10^{b}
SE±			2.31		

All means within a column (for each factor) followed by same letters are not significantly different at 5% level of significance. MR= Manual ridging, MT = Minimum tillage, SE = Standard error,

Crop parameters as affected by tillage and split nitrogen fertilization

The seedling emergence and plant heights at different growth stages of maize are shown in Table 6. The effects of tillage and N fertilization on seedling emergence were not significant. Effect of tillage on plant height was significant at all the growth stages of maize with maize in MR having significantly higher height than MT. Similar results of reduced plant height of maize under minimum tillage compared to conventional tillage have been reported by Shivay and Singh (2000). Contrary to results of tillage practice, N fertilization had a significant effect on seedling emergence. Split application of N at 30 + 60 kg N ha^{-1} had seedling emergence of 93 % which was significantly lower than that of the other treatments. The application of N had significant effect on the plant height at tasseling growth stage and at physiological maturity. Nitrogen application whether split applied or not, produced taller plants than the zero N treatment. Plants that are not fertilized with N usually have retarded growth including lack of production of reproductive cells. Plants must have adequate nitrogen before it can synthesize cells and lack of nitrogen could halt the process of growth and reproduction (Thompson and Troeh, 1978). The higher rates of N recorded plants with significantly higher heights than plants in the lower N rate and in the control treatment. Similar results of increased plant height with increasing levels of N fertilization have been reported by Maqsood *et al.* (2001). This result is an indication that higher levels of nitrogen fertilizer promote the vegetative growth in maize and its deficiency reduces the vegetative growth. This agrees with Onasanya *et al.* (2009) who reported higher application rate of nitrogen produced higher plant height and grain yield. The interaction effects of tillage and N fertilization on seedling emergence and plant height were not significant.

The effects of tillage and N fertilization on grain and stover yields of maize are presented in Table 7. Tillage had a significant effect on both grain and stover yields. Manual ridging produced significantly higher grain and stover yields, 1.3 and 4.1 Mg ha^{-1} respectively, compared to MT. The lowest yields observed in the minimum tillage may be attributed to soil surface crusting resulting in surface runoff, nutrient loss and reduced infiltration, and hence greater plant-water stress compared to manual ridging. Similar results have been reported by another researcher (Khattack *et al.,* 2005). Significant effect of N fertilization was observed on both grain and Stover yields confirming N as the most limiting nutrient to maize production in the southern Guinea savanna of Nigeria (Adeboye *et al*., 2020). The split nitrogen fertilization (60 + 30 kg N ha^{-1}), recorded significantly higher grain and stover yields which were significantly higher than that of the control treatment having the lowest grain and stover yields of 0.6 and 2.0 Mg ha^{-1} respectively. Similarly, Singh and Sharma (2001) also observed that grains yield increased significantly with increasing nitrogen levels up to 150 kg N ha^{-1}.

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Table 6: Effects of tillage and split nitrogen fertilization on seedling emergence and plant height at growth stages of maize.

Treatment Tillage (T)	Seedling E (%)	Plant 2 WAP	Height (cm) Tasseling	Physiological maturity
MR	95^{a}	26.20^{a}	139.67^{a}	169.73^{a}
MT	95a	22.07^{b}	116.27^{b}	155.87^{b}
SE ±		1.22	5.36	4.62
N rate (kgNha^{-1})				
0	95^{ab}	24.00^{a}	110.33^{c}	141.00^{b}
30 + 60	93^{c}	23.33^{a}	117.67^{bc}	153.00^{b}
45 + 45	95^{ab}	24.33^{a}	130.33^{ab}	169.00^{a}
60 + 30	95^{ab}	25.00^{a}	139.83^{a}	174.50^{a}
90	96^{ab}	24.00^{a}	141.67^{a}	176.50^{a}
SE ±	1.15	1.93	8.48	7.29
Interaction				
T x N	NS	NS	NS	NS

All means within a column (for each factor) followed by same letters are not significantly different at 5% level of significance .MR= Manual ridging, MT = Minimum tillage, NS = Not significant at 5% level

Table 7: Effects of tillage and split nitrogen fertilization on grain and stover yields

Treatment Tillage (T)	Grain Yield (Mg ha^{-1})	Stover Yield
MR	1.3a	4.1a
MT	1.2b	3.7b
SE ±	0.01	0.31
N rate (Kg N ha^{-1}) (N)		
0	0.6c	2.0c
30 + 60	1.6b	5.2b
45 + 45	1.8ab	5.2ab
60 + 30	2.2a	5.9a
90	1.8ab	5.8ab
SE ±	0.22	0.60
Interaction		
T x N	NS	NS

All means within a column (for each factor) followed by same letters are not significantly different at 5% level of significance. MR= Manual ridging, MT = Minimum tillage, SE =Standard error, NS = Not significant at 5% level

CONCLUSION AND RECOMMENDATIONS

This study evaluated the effects of minimum tillage and manual ridging on soil organic carbon and the performance of maize as part of a broad study to promote conservation agriculture in the southern Guinea savanna of Nigeria. The findings of the study indicate manual ridging enhanced the soil organic carbon content and produced the highest maize yields. Thus, it may seem

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to be the most appropriate for maize cultivation in the agro ecological zone. As expected, results showed that N is important in maize production and best applied in split form.

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